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Numerical modeling of parallel-plate based AMR

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Numerical modeling of parallel-plate based AMR

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Outline

- The Danish effort in magnetic refrigeration
- Focus on the modeling
- Results from both experiment and modeling
- Discussion

Risø's work on magnetic refrigeration

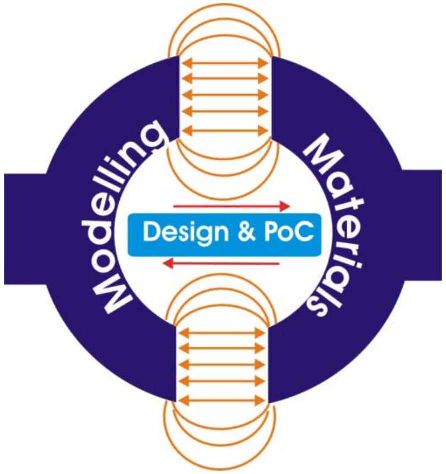
Partnership between

Duration: 4 years

- **Starting date: 01.01.2007**
- **Ending date: 31.12.2010**

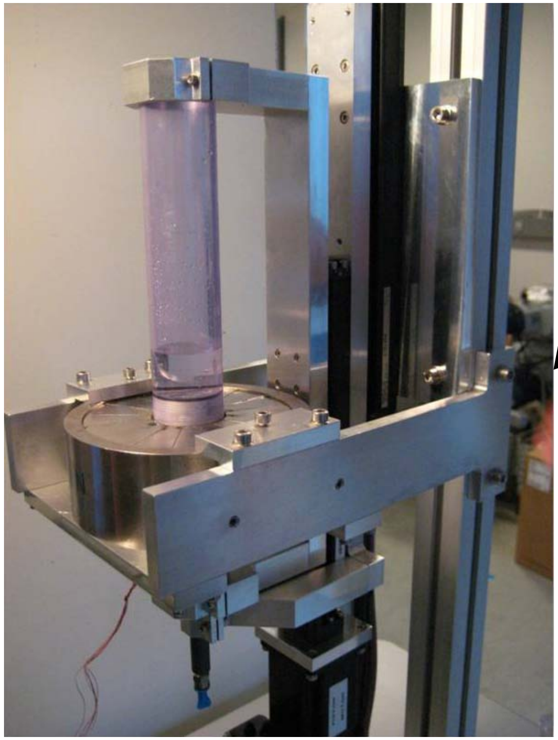
Funding: € 2.6M

- **5 Ph.D. students**
- **3 Postdocs**

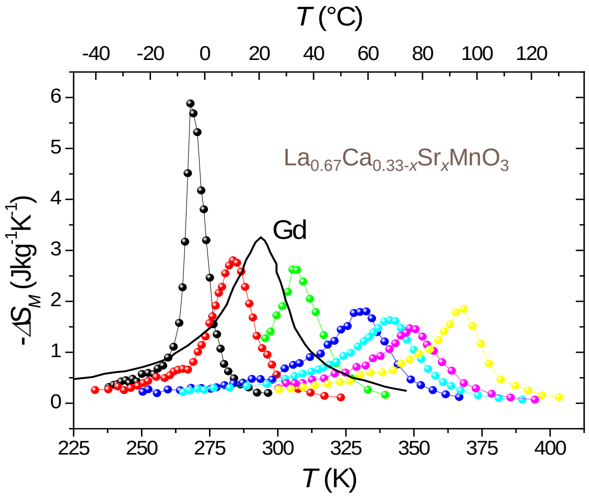


Challenges
Demonstrate cost-effective systems at commercially relevant temperature spans with high efficiency and environmentally friendly materials

Configuration of our effort

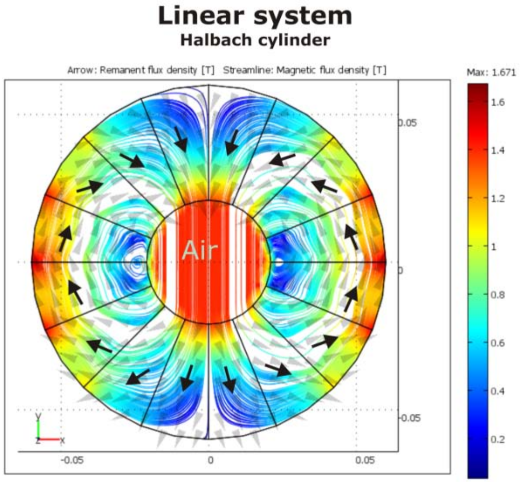


Development of prototype

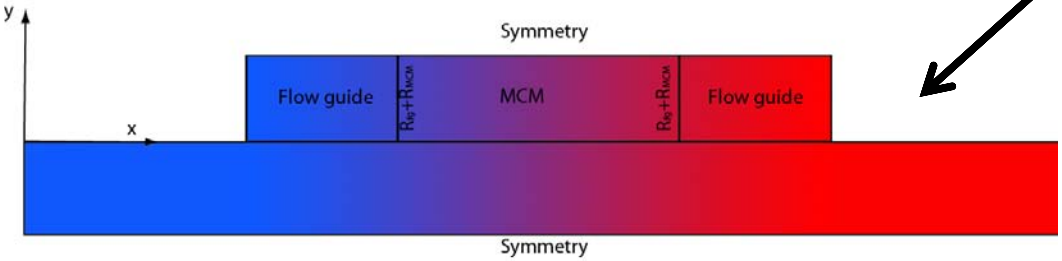


Materials research:

- New materials
- Characterization, evaluation and processing of relevant materials

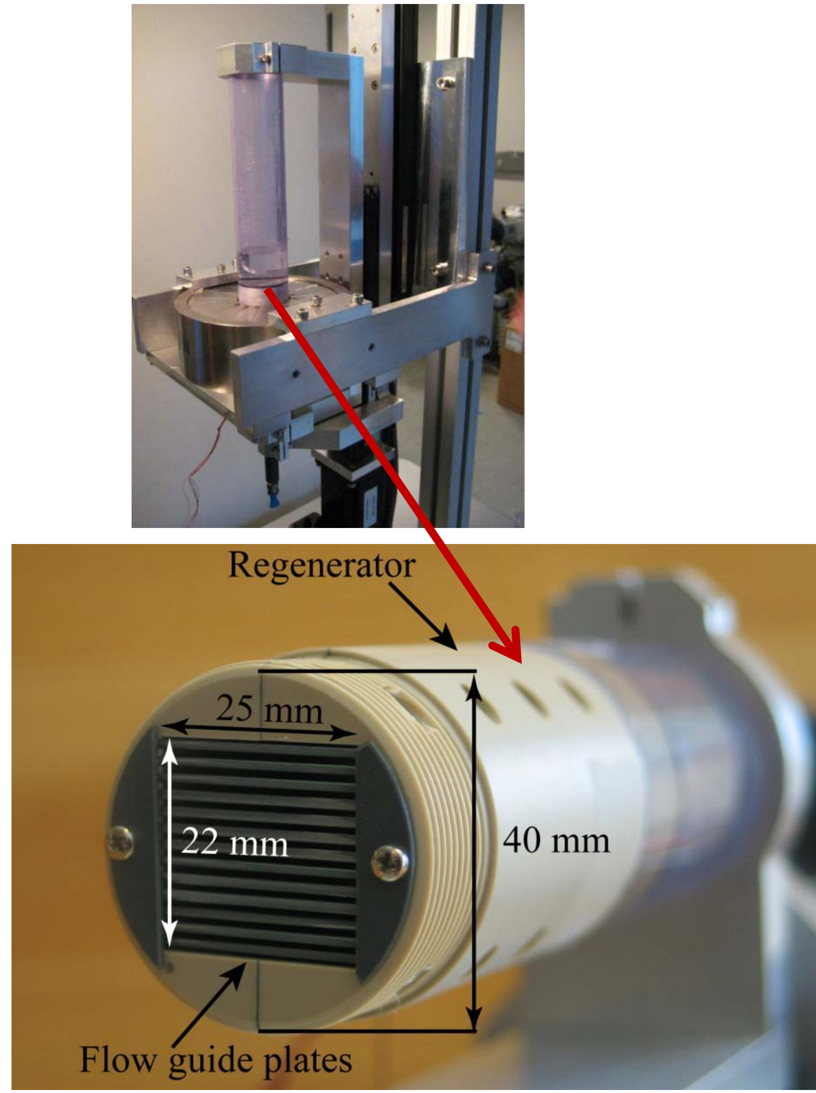


Modeling of both AMR and permanent magnet



Details on the experiment

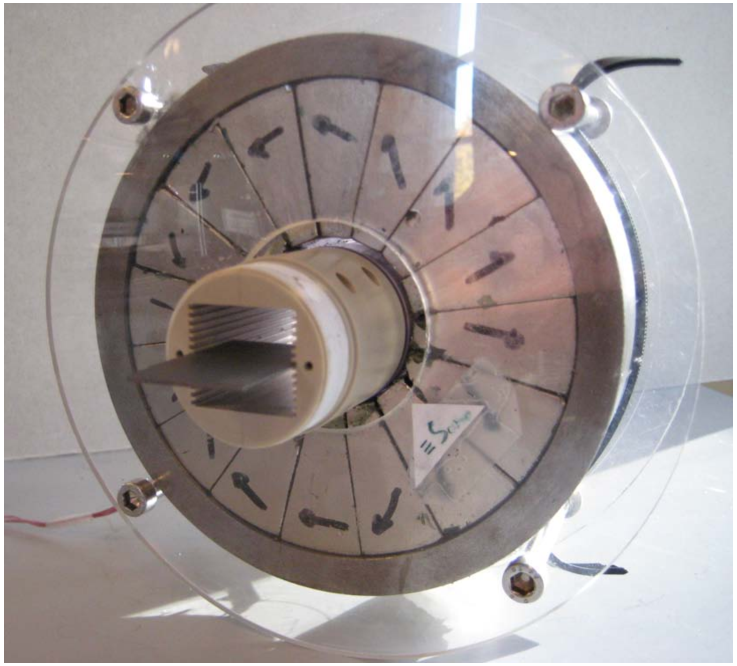
- Parallel plate based AMR
- Reciprocating
- Permanent magnet
- Materials used include Gd and $LaCaSrMnO_3$
- Plate thickness from 0.3 to 0.9 mm
- Channel thickness from 0.5 to 1.0 mm

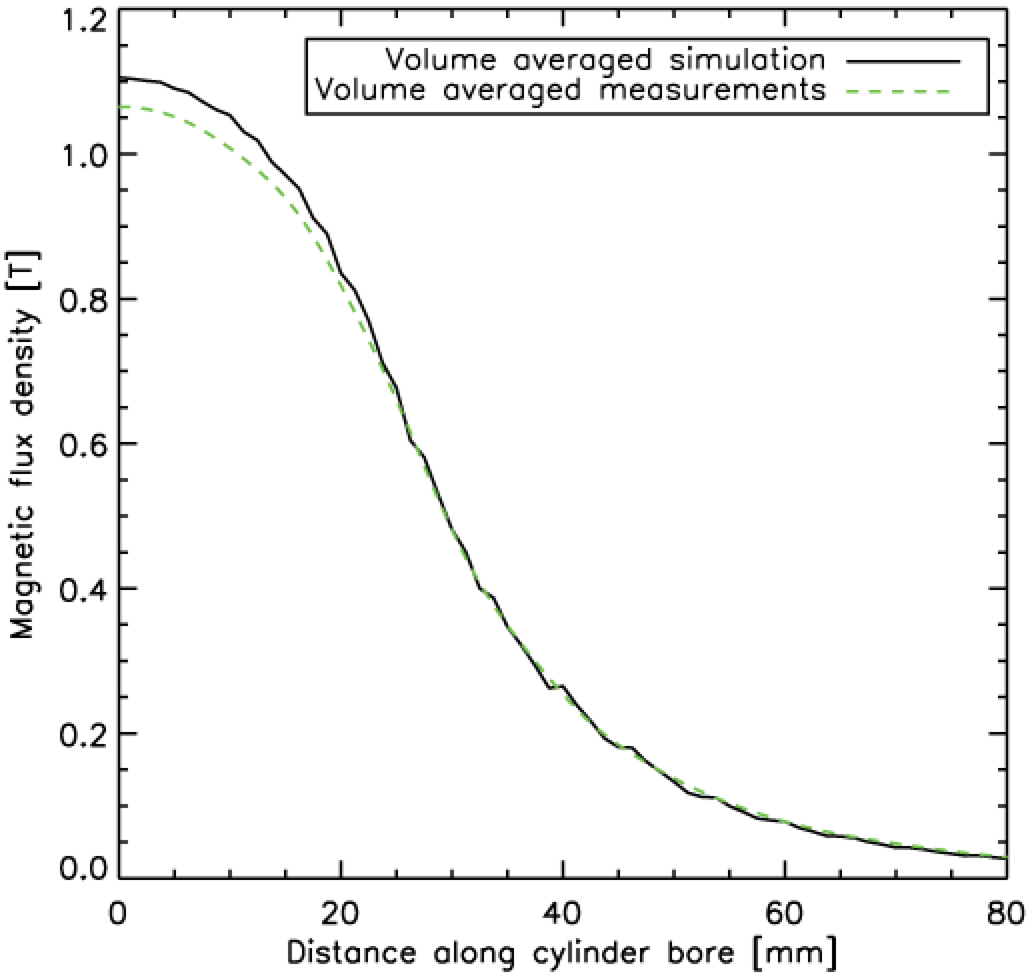


Plates for the regenerator

Example of $La_{0.67}Ca_{0.26}Sr_{0.07}Mn_{1.05}0_3$ plates
(40x25x0.3 mm)

The permanent Halbach magnet



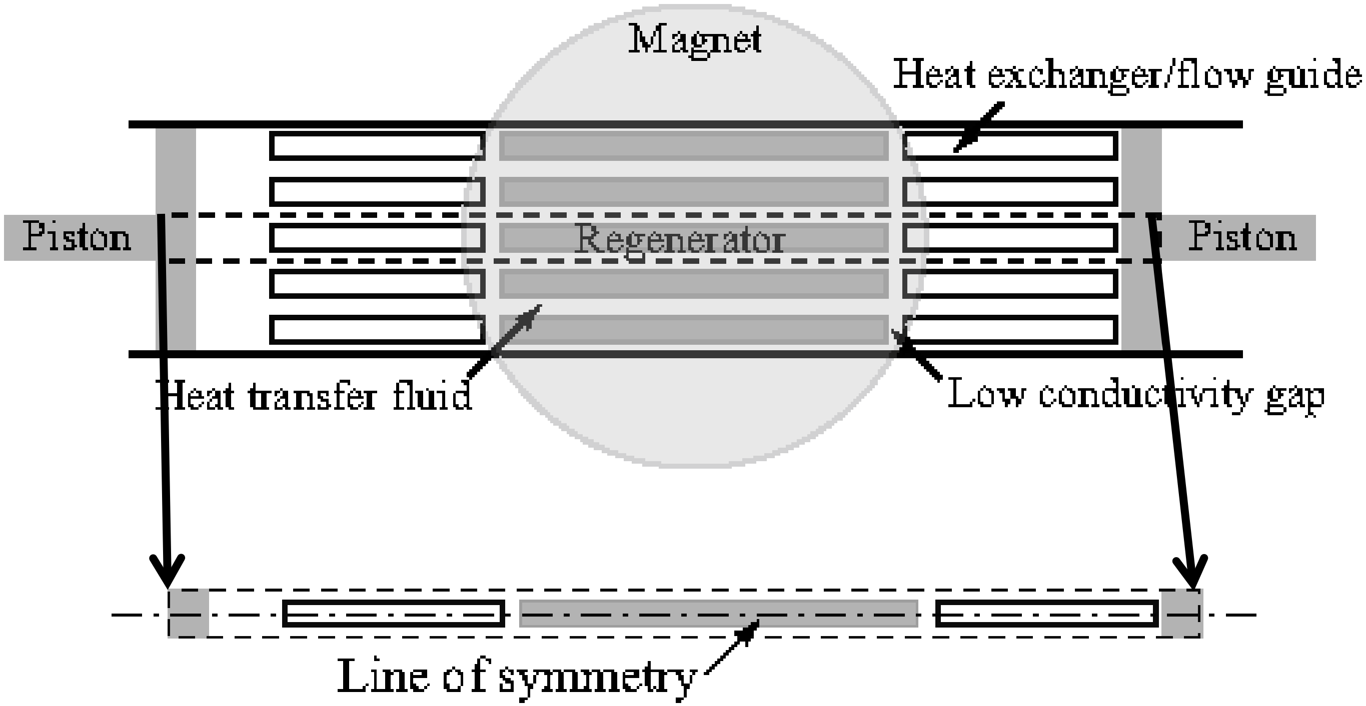


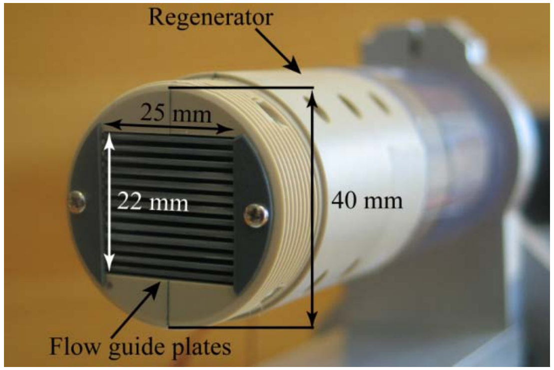
Numerical AMR modeling

Key features of our numerical AMR model

- 2.5-dimensional
- Parallel-plate based
- Versatile
- Fast!

Schematic of the model



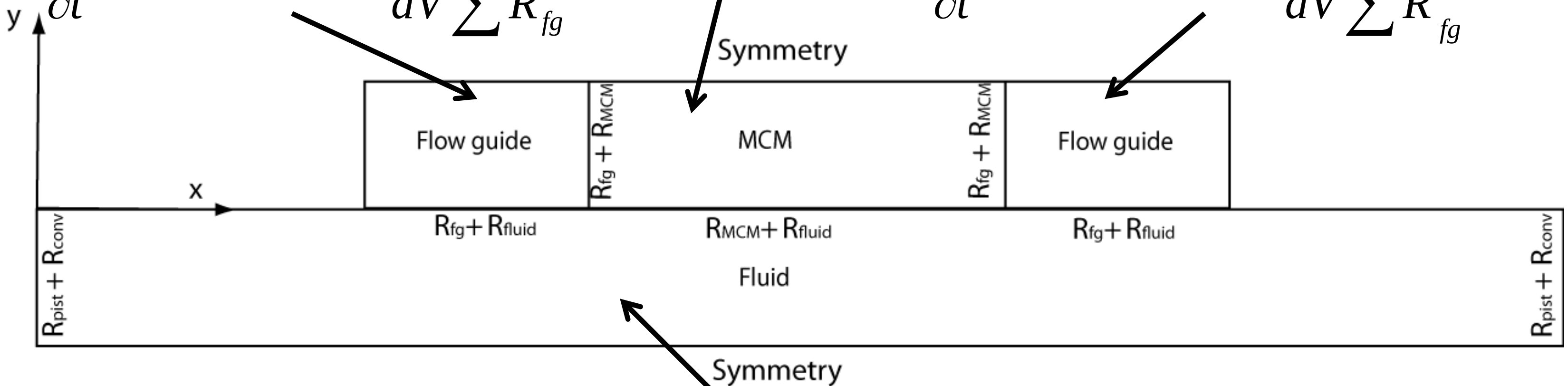


Details of the model

$$\rho_{MCM} c_{p,MCM} \frac{\partial T_{MCM}}{\partial t} = k_{MCM} \nabla^2 T_{MCM} + Q_{MCE} + \frac{T_\infty - T_{MCM}}{dV \sum R_{MCM}} + Q_{bdry}$$

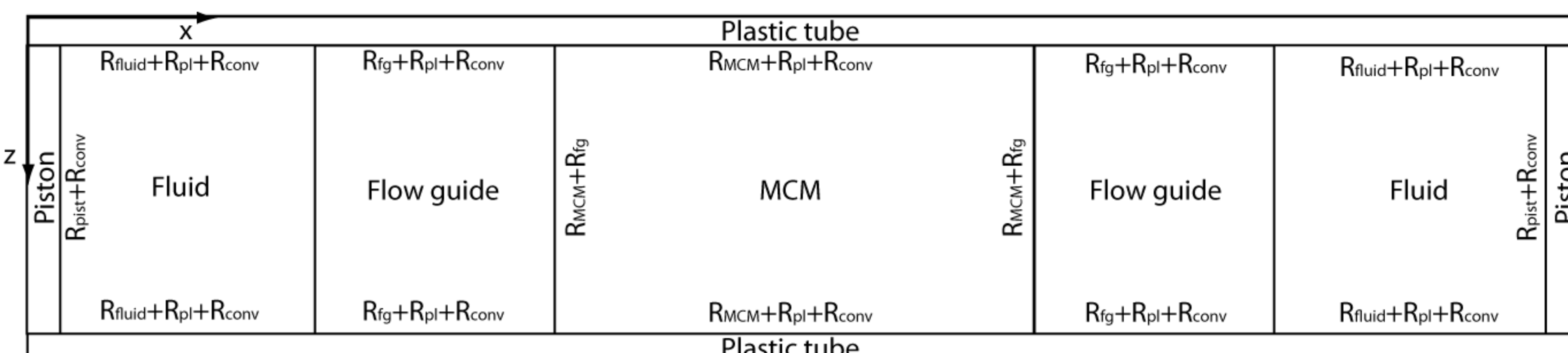
$$\rho_{fg} c_{p,fg} \frac{\partial T_{fg,1}}{\partial t} = k_{fg} \nabla^2 T_{fg,1} + \frac{T_\infty - T_{fg,1}}{dV \sum R_{fg}} + Q_{bdry}$$

$$\rho_{fg} c_{p,fg} \frac{\partial T_{fg,2}}{\partial t} = k_{fg} \nabla^2 T_{fg,2} + \frac{T_\infty - T_{fg,2}}{dV \sum R_{fg}} + Q_{bdry}$$



$$\rho_{fl} c_{p,fl} \left(\frac{\partial T_{fl}}{\partial t} + u \cdot \nabla T_{fl} \right) = k_{fl} \nabla^2 T_{fl} + \frac{T_\infty - T_{fl}}{dV \sum R_{fl}} + Q_{bdry}$$

Details of the model

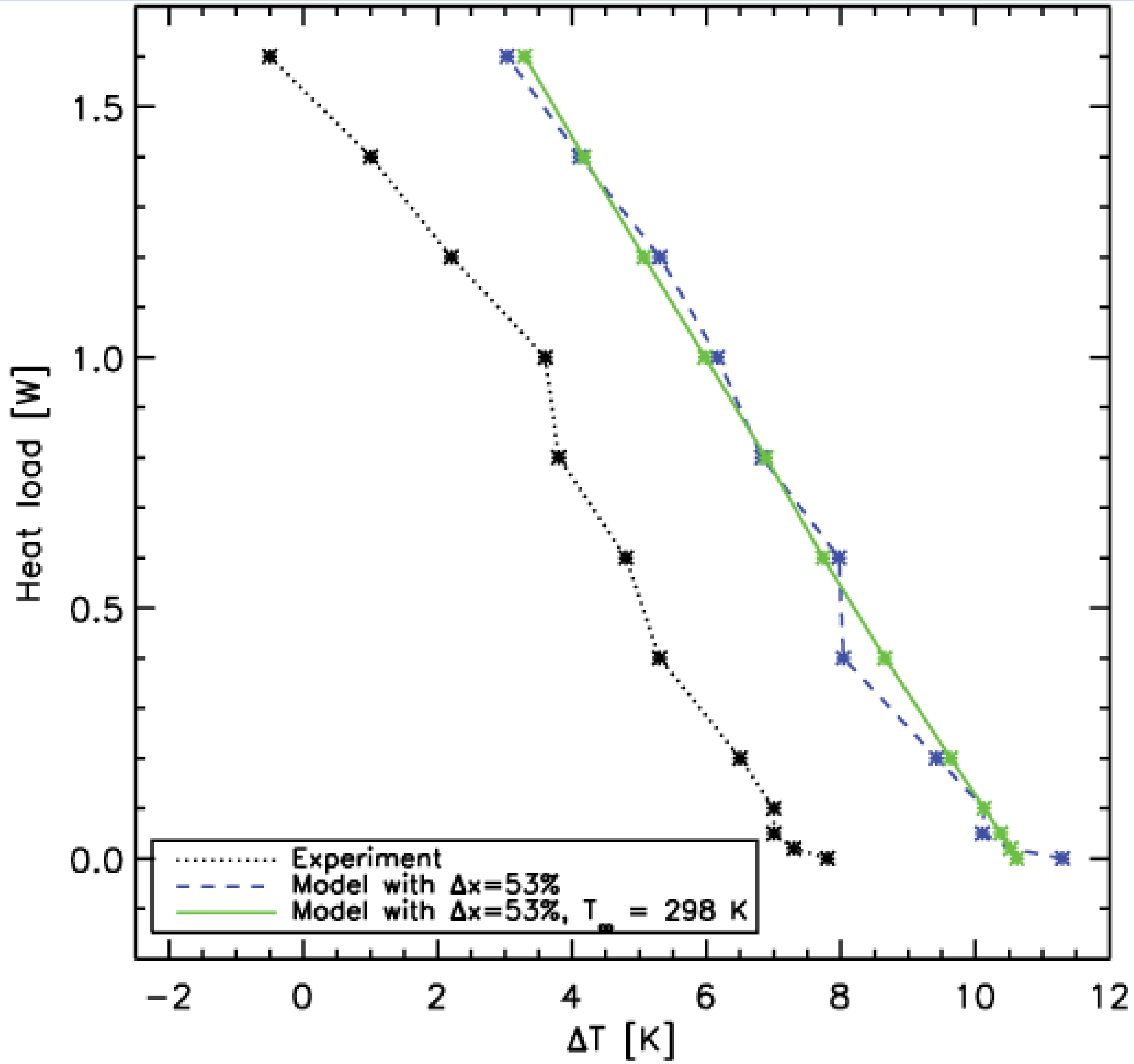


Experiments and modeling

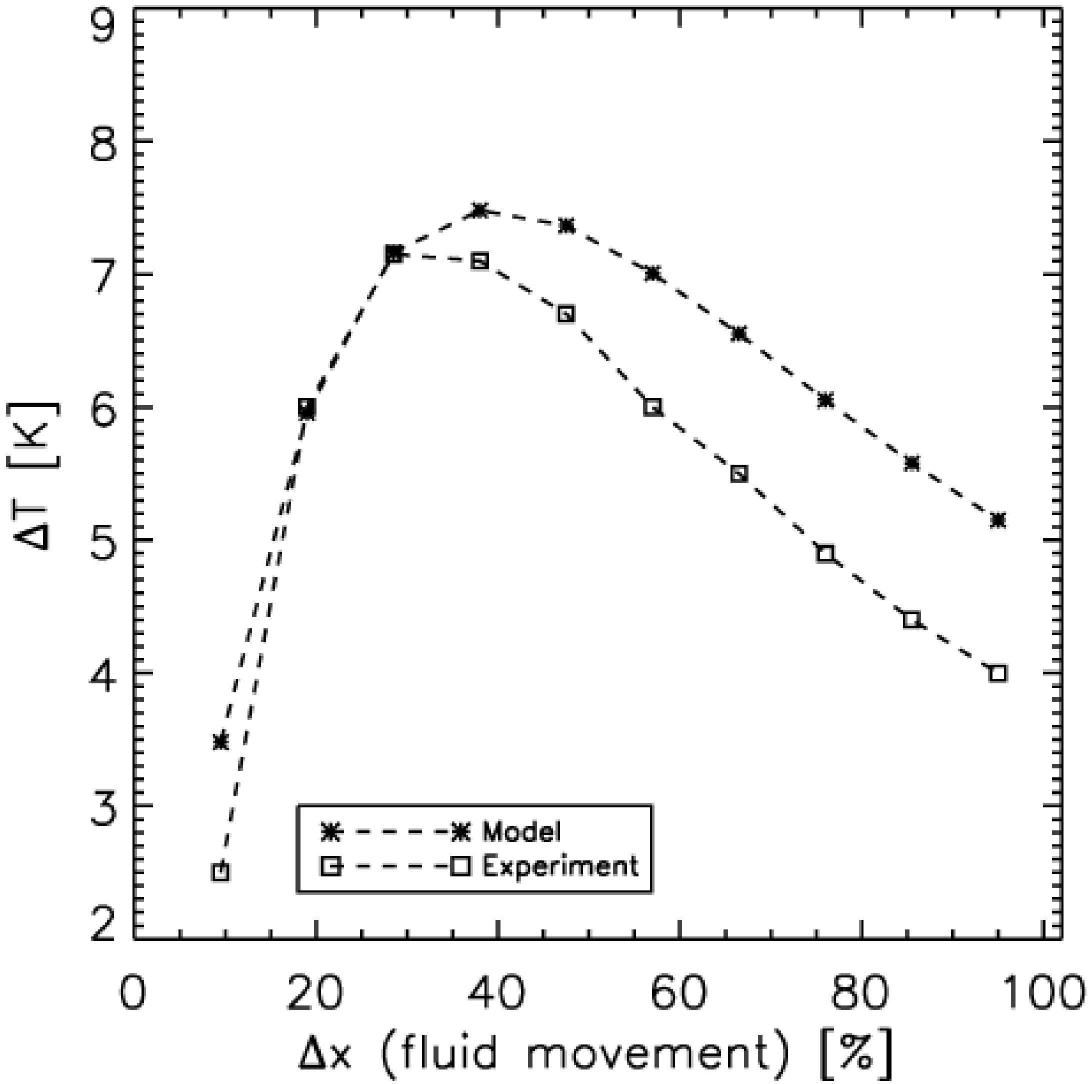
Each experiment was configured as follows

- 13 plates of commercial grade Gd (92 g)
- Plate thickness: 0.9 mm
- Channel thickness: 0.8 mm
- A cycle timing of 9 s

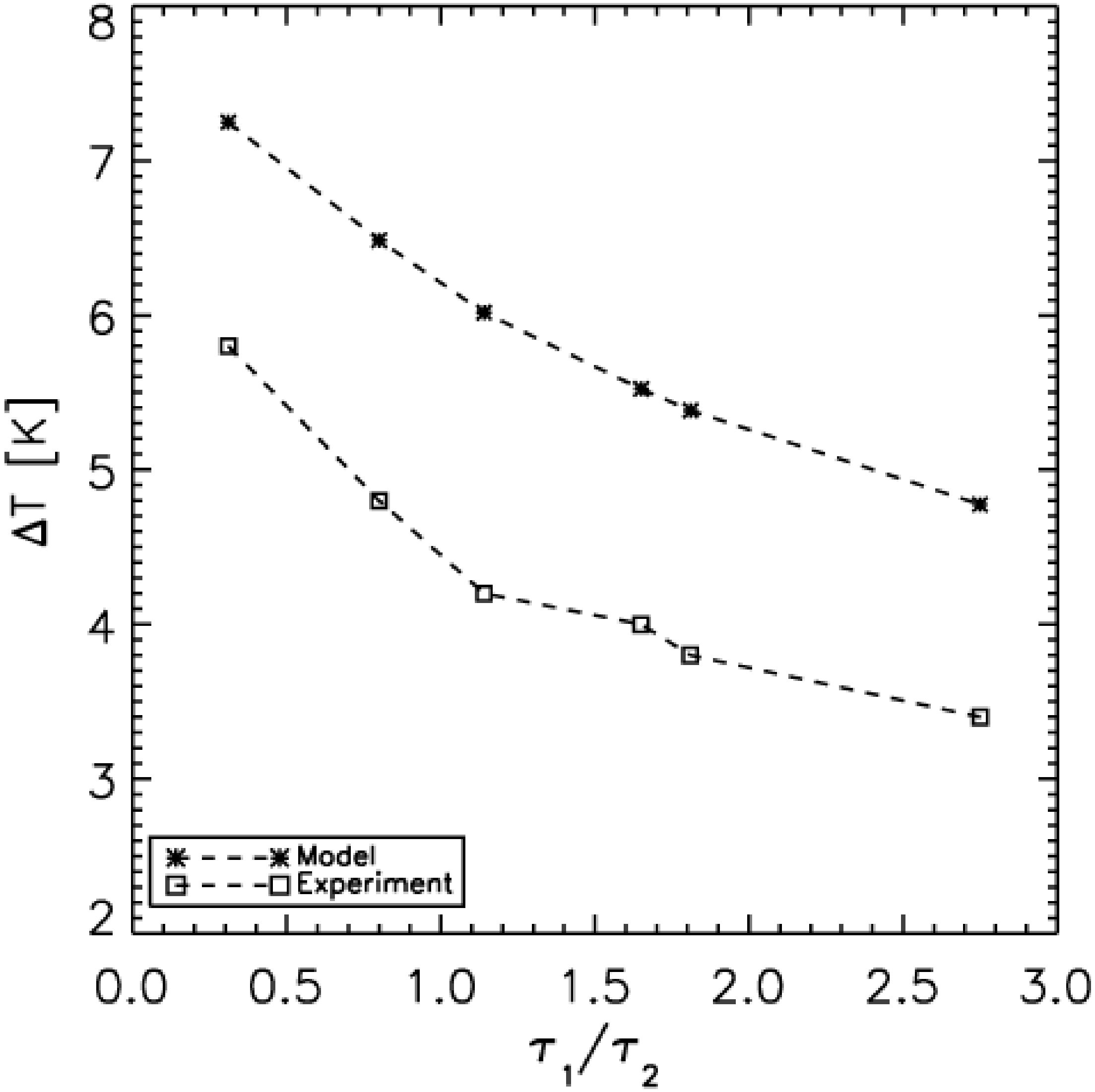
Heat load results



Fluid movement results



Timing results



Summary and Conclusion

- A versatile experimental AMR was presented
- A corresponding advanced 2.5D numerical model was described
- Selected results from experiment and model were compared and to a certain extent the agreement is satisfactory

Future work

- Further development of the model to include e.g. passive regeneration and composite materials
- Present large range of experiments with corresponding modeling of various materials
- Detailed study of demagnetization effects
- Work on composite materials

References

- Petersen, T. F.; Pryds, N.; Smith, A.; Hattel, J.; Schmidt, H. & Knudsen, H.
  ”Two-dimensional mathematical model of a reciprocating room-temperature Active Magnetic Regenerator”
  International Journal of Refrigeration, **2008***, 31*, 432-443
- Bjørk, R.; Bahl, C. R. H.; Smith, A. & Pryds, N.
  “Optimization and improvement of Halbach cylinder design”
  Journal of Applied Physics, AIP, **2008***, 104*, 013910
- Bahl, C.; Petersen, T.; Pryds, N. & Smith, A.
  ”A versatile magnetic refrigeration test device”
  Review of Scientific Instruments, **2008***, 79*, 093906